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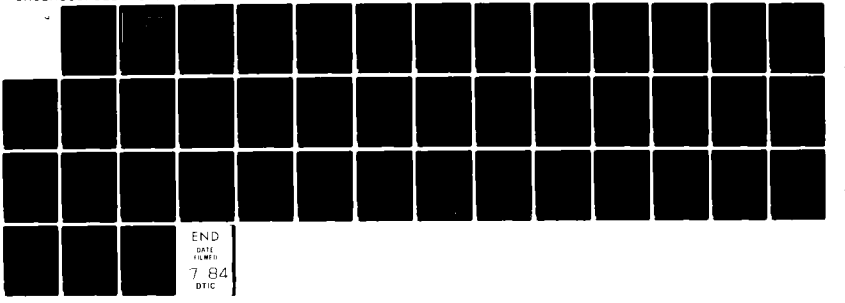

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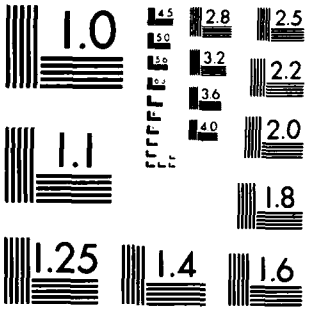

PILOT FIELD TESTING OF ARCTIC ENGINE OIL IN ARMY COMBAT/ TACTICAL VEHICLES AT FT. CARSON, CO AND FT. LEWIS, WA

INTERIM REPORT
AFLRL No. 157

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Military lube orders for combat and tactical equipment specify use of a single-viscosity grade lubricant with the grade depending on seasonal or climatic conditions. The use of this oil results in seasonal oil changes, regardless of the condition of the oil. Also, standard issue oils do not offer sufficient lubrication and engine protection over a wide range of ambient temperatures such as those experienced at Fort Carson, CO, and Fort Lewis, WA. To address lubrication problems experienced at these bases, a

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20. ABSTRACT (Cont'd)

pilot field test was initiated utilizing two multiviscosity lubricants qualified under MIL-L-46167 (OEA). Data derived from the test were also to be used as a basis for developing multigrade engine oils for Army tactical/combat equipment and to gain supplemental information covering the use of arctic engine oil (OEA) over expanded temperature ranges. This report covers the field test initially utilizing three M60A1 tanks at Fort Carson, CO, later expanding in scope to five additional M60A1 tanks and four M151A2 jeeps at Fort Carson. The M151A2 jeeps (1/4-ton trucks) were equipped with specially manufactured low blowby pistons and piston rings and were added to the test to evaluate the durability of the piston and piston ring package. Also added to the test were six M60A1 tanks located at Fort Lewis, WA.

Subjective comments by operating and maintenance personnel indicated that all the engines lubricated by the MIL-L-46167 oil started easier, and that the M60A1 tank engines appeared to develop more power. In addition, maintenance personnel at Fort Carson noted that the M60A1 tank engines lubricated with the MIL-L-46167 oil experienced a much lower usage rate for lead-acid (6TN) storage batteries and main engine generators and starters.

Concern was expressed by operating personnel at Fort Carson about the AVDS-1790 engines overheating when being lubricated by the MIL-L-46167 oil. However, this concern abated after a field test comparing the change in crankcase temperatures between vehicles lubricated with the MIL-L-2104C oils and those lubricated with the MIL-L-46167 oil indicated no significant differences or adverse effects.

Transmissions and final drives could be successfully lubricated with the MIL-L-46167 arctic engine oil as could the modified M151A2 jeep engines, although leaking gaskets and seals were more prevalent for those engines. Further study and testing are indicated for resolving the questions raised.

FOREWORD

This report was prepared by the U.S. Army Fuels and Lubricants Research Laboratory (AFLRL) located at Southwest Research Institute, San Antonio, Texas, under Contracts No. DAAK70-80-C-0001 and DAAK70-82-C-0001. The work was sponsored by U.S. Army Belvoir Research and Development Center, Materials, Fuels, and Lubricants Laboratory, Fort Belvoir, Virginia. The Project Monitor and Contractor Officer's Representative was Mr. F.W. Schaekel, Belvoir R&D Center, STRBE-VF, Fort Belvoir, Virginia. Acknowledgement is given to Mr. M.E. LePera of Belvoir R&D Center and Messrs. S.J. Lestz and A.A. Johnson of AFLRL for their participation, encouragement, and suggestions. Special acknowledgement is given to Mr. Chester Johnson of Fort Carson, Colorado, and Mr. Joseph Geraci of Fort Lewis, Washington, for assistance provided throughout the program.

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I. INTRODUCTION

Engine crankcase oils, presently furnished under Military specifications for use in combat and tactical ground equipment, are predominantly single viscosity-grade lubricants. Application of these oils is governed by equipment lubrication orders which require the use of individual grade products over specific ambient temperature ranges.(1)* This method of application has resulted in frequent lubricant changes solely in response to seasonal/climatic temperatures and has led to the disposal of significant quantities of otherwise usable oil. To minimize the disposal problems and reduce maintenance associated with oil changes, attempts have been made to expand usage of individual grade products to temperatures lower than those recommended by the equipment lubrication orders. These attempts, although occasionally successful, have resulted in operational problems and equipment malfunctions.

The aforementioned problems were highlighted by occurrences associated with the operation of M60 tanks at Fort Carson, Colorado.(2,3) Because of the altitude and locale, Fort Carson experiences wide temperature fluctuation during the year. This is especially evident in the early spring and autumn when daily ambients can change by as much as 28°C (50°F). These temperature fluctuations require frequent oil changes and excessive maintenance to comply with vehicle lubrication orders. Attempts to avoid oil changes by servicing equipment with higher viscosity Grade 30 and 50 MIL-L-2104C (4) products resulted in severe startability problems. Also, there was an indication that a portion of the equipment malfunctions being experienced were related to use of the higher viscosity lubricant.

Pilot field testing was conducted at Fort Carson, CO and Fort Lewis, WA. The objective of the testing was to evaluate the capability of MIL-L-46167 (5) arctic oil (OEA) to provide an interim solution to the lubrication problems being encountered. In addition, the data derived from the test were to be used as a basis for developing multigrade engine oils for Army tactical and combat equipment and to gain supplemental information covering the use of OEA lubricant over expanded temperature ranges.

*Underscored numbers in parentheses refer to the list of references at the end of this report.

II. FORT CARSON TESTING

A. Details of Test

1. Test Materials

Two types of lubricants were used throughout the test. The test oil was a multiviscosity, synthetic lubricant qualified for military use according to MIL-L-46167 specification. This OW-20 grade engine lubricant was developed for use in the arctic and was previously identified by Aberdeen Proving Ground Purchase Description No. 1 (APG PD-1). It has been successfully tested in high-output diesel engines under arctic conditions (-55°C to +5°C) and is currently in use by the Military during arctic operations.

The second lubricant was stock issue MIL-L-2104C OE/HDO 30 or 50 grade, depending on seasonal requirements and applicable lubrication orders. Since the standard issue oil was and is supplied by different companies and manufactured within specification tolerances, it was referred to simply as MIL-L-2104C. Table 1 gives a description of the two lubricants and some of their properties. The data for the MIL-L-2104C oil are represented as "typical" for standard issues of that oil.

TABLE 1. DESCRIPTION OF TEST LUBRICANTS

Description	ASTM Method No.	Oil A	Oil B (Typical)
Specification		MIL-L-46167*	MIL-L-2104C
Grade		Arctic, OEA	OE/HDO-30
Properties			
Viscosity, cSt	D 445		
at 99°C (210°F)		6.14	11.90
at 38°C (100°F)		29.3	120.0
Viscosity Index	D 2270	185	96
TAN	D 664	0.2	2.0
TBN	D 2896	7.8	12.0
Flash Point, °C (°F)	D 92	238 (460)	227 (440)

*Formerly designated APG PD-1.

The fuel used during the program was that available through the military supply system and was procured against VV-F-800B specification.

2. Test Fleet

a. M60A1 Tanks

The initial pilot fleet consisted of three M60A1 tanks at Fort Carson CO. These vehicles were powered by the AVDS-1790-2A, a twelve-cylinder, air-cooled diesel engine. Two of the test vehicles (HQ-67 and HQ-68) were lubricated with MIL-L-46167 arctic oil. Initially, one vehicle (HQ-66) was operated as a control vehicle using a typical MIL-L-2104C OE/HDO-30 lubricant. Only the crankcase of each engine was charged with the test lubricants.

The three vehicles were operated by the 1/77 Armor, which also provided organizational maintenance and repair work. If more than organizational maintenance was required, the engine was removed and forwarded to the DIO Maintenance Division for rebuild. The condition of the engine oil was monitored by the Army Oil Analysis Program laboratories, initially at Tracy, CA, then later at Fort Carson. Table 2 gives the prior engine history for each of the three engines that was used in the test from January 1977 through 20 April 1977.

TABLE 2. ENGINE HISTORY FOR TEST AND CONTROL VEHICLES

Bumper No.	Type of Engine	Engine Order	Engine Hours	Engine Miles	Type Oil	Remarks
Hq. 66	AVDS-1790-2A	Original	181	1433	OE/HDO-30	---
Hq. 67	AVDS-1790-2A	3rd Engine	68	541	MIL-L-46167	---
Hq. 68	AVDS-1790-2A	4th Engine	69	383	MIL-L-46167	Repaired*

* Maintenance Division - 11 Mar 76 - 1 cylinder & piston replaced. Other cylinder 7300 psi Dyno run - 675 HP + 108 = 783 hp issued.)

Because no adverse results were observed during this brief test period for the AVDS-1790-2 engines, it was decided to evaluate the test oils' effectiveness in lubricating/protecting M60A1 tank transmissions and final drives as well. Until arrangements could be made, the original vehicles remained operational on their

respective lubricants. However, little operational data were reported during this period due to changes in personnel and the fact that the program had not yet been officially extended. On 10 August 1977, the program was expanded to include five additional M60A1 vehicles. These vehicles were identified as vehicles Nos. A-31, A-32, A-33, A-34, and A-35. All five vehicles were converted to the arctic engine oil for a total of seven M60A1's operating on synthetic arctic engine oil, and one M60A1 using MIL-L-2104C lubricant being designated as a control vehicle. Table 3 gives the description of the five additional M60A1 tanks.

TABLE 3. DESCRIPTION OF FIVE ADDITIONAL TANKS ADDED 10 AUG 1977

Bumper No.	Vehicle SN	Engine SN	Engine Mileage	Type Oil
A-31	5747	8860	169	MIL-L-46167
A-32	6990	21027	1979	MIL-L-46167
A-33	3632	6546	1657	MIL-L-46167
A-34	5924	2508	668	MIL-L-46167
A-35	2894	3313	311	MIL-L-46167

At this time, it was reported that the control vehicle originally identified as Hq. 66 had now become B-11. This was a record change only since the bumper number had been changed, not the vehicle itself. On 9 June 1978, the plan to include the transmissions of all the M60A1 tanks and the final drives for Hq. 67 only was put into effect. In October 1978, data began to appear in monthly data and evaluation reports prepared by the test unit's battalion maintenance officer about an M60 tank with a bumper number of Hq. 66. This vehicle was not the same Hq. 66 identified at the beginning of the test which was redesignated as B-11. Data on the new Hq. 66 was sketchy until June 1979 from which time it appeared regularly until the end of the test. Since it was operated with MIL-L-2104C, it became a reliably observed control vehicle in addition to B-11 for the period June 1979 through February 1981.

b. M151A2 Jeep

Four M151A2 jeeps were placed in the pilot test program. The engines in the jeeps were provided with specially machined low blowby pistons and piston rings. The purpose of having the jeeps in the test was to evaluate the durability of the piston and piston ring package. In April 1977, the first of the four jeeps was started in the test program. Test data for this vehicle, Hq-9, began to arrive on a regular basis in September 1977. The remaining three jeeps were started in the test on 24 February 1978. Test data for the three jeeps began to arrive on a regular basis in April 1978. Table 4 gives a description of the four jeeps used in the pilot fleet test.

TABLE 4. DESCRIPTION OF TEST M151A2 JEEPS

Unit	Vehicle Type	Vehicle SN	Bumper No.	Engine SN	Engine Mileage	Oil
1/77 Armor	M151A2	Unknown	Hq-9	Unknown	1888	MIL-L-46167
19th MP Bn	M151A2	02D94572	P-7	5004337	13120	MIL-L-46167
19th MP Bn	M151A2	02E58172	P-17	5004614	18725	MIL-L-46167
19th MP Bn	M151A2	02G48172	P-73	5006562	25395	MIL-L-2104C

In September 1980, vehicle P-7 was involved in an accident which totalled the vehicle. However, there was no damage to the engine, and it was installed in vehicle P-41 for the remainder of the test.

3. Fleet Operations

a. M60A1 Tanks

All the M60A1 tanks in the test were operated in accordance with normal mission/training requirements. Table 5 shows a summary of vehicle operation for the period January 1977 through 20 April 1977.

During the period 15 September to 15 November 1977, the vehicles were involved in extensive training maneuvers. Tank commanders reported that vehicles operating on the arctic engine oil tended to operate at a higher engine temperature than experienced with vehicles using OE/HDO-30 oil. The situation was described

as serious as the AVDS-1790-2A (non-RISE) engines ran in the "red" zone of the temperature gage after only 3-5 miles of operation and had to be cooled down before further operation. The AVDS-1790-2D (RISE) engines also ran hotter than normal but not in the "red" zone. This potential overheating was investigated during August 1979 at Fort Carson.(6,7) Two M60A1 non-RISE and two M60A1 RISE* engines were instrumented to measure the engine oil temperatures at the oil filter bypass valve and within the oil pan. For each engine configuration, one vehicle used a conventional MIL-L-2104C OE/HDO-50 lubricant, while the other vehicle of the pair was lubricated with the MIL-L-46167 test lubricant. The vehicles were then operated simultaneously over a test course which produced high engine temperatures. Figure 1 shows that the non-RISE configuration had an observed 5° ± 1°C average increase in oil temperature with the MIL-L-46167 arctic oil; the maximum sump temperature measured was 149°C during a hot soak with the engine stopped. Figure 2 shows that the RISE engines had no significant differences in oil temperature with the maximum oil sump temperature achieved being 121°C. The two large drops in temperature experienced during the test are a result of the two scheduled maintenance stops at 10 and 20 miles into the test. As Figures 1 and 2 illustrate, the temperature difference between mineral and synthetic lubricants is small, taking into account the different starting temperatures of the vehicles. This slight difference would not be expected to result in any operational difficulties, since this represents only 3 percent of the peak temperatures encountered during vehicle operation.

TABLE 5. SUMMARY OF VEHICLE OPERATIONAL DATA
January 1977 Through 20 April 1977

Bumper No.	Type Oil	Oil Used (Qts)	Fuel Used (Gal)	Miles Traveled	Hours Operated
Hq. 66	OE/HDO-30	28	350	286	54
Hq. 67	MIL-L-46167	20	330	302	49
Hq. 68	MIL-L-46167	20	513	478	82

A major problem arose during the test concerning the air filtration system for the M60's. The performance of this system was inadequate and allowed the engines to injest large quantities of dust, dirt and silicon as to damage the

*Reliability-Improved Selected Equipment

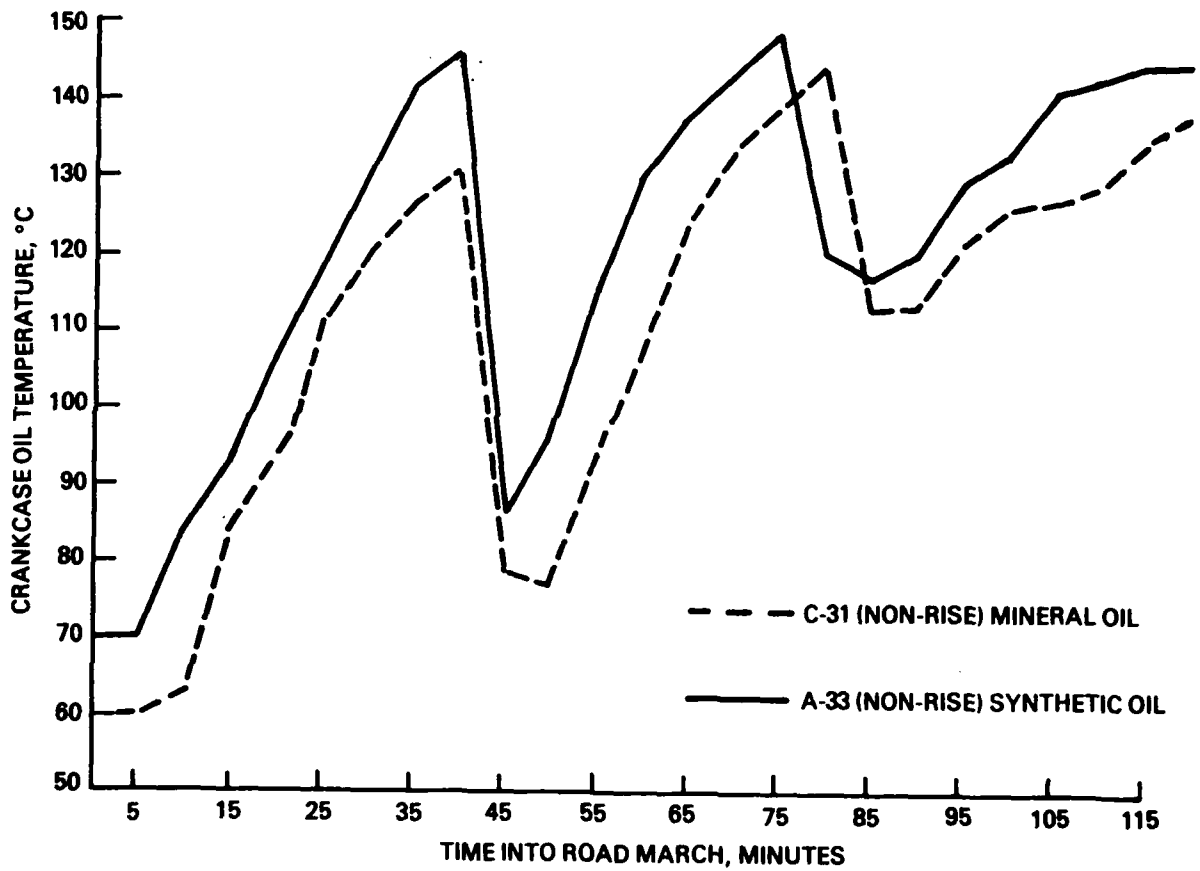

FIGURE 1. ENGINE OIL TEMPERATURE VS TEST TIME FOR NON-RISE ENGINES

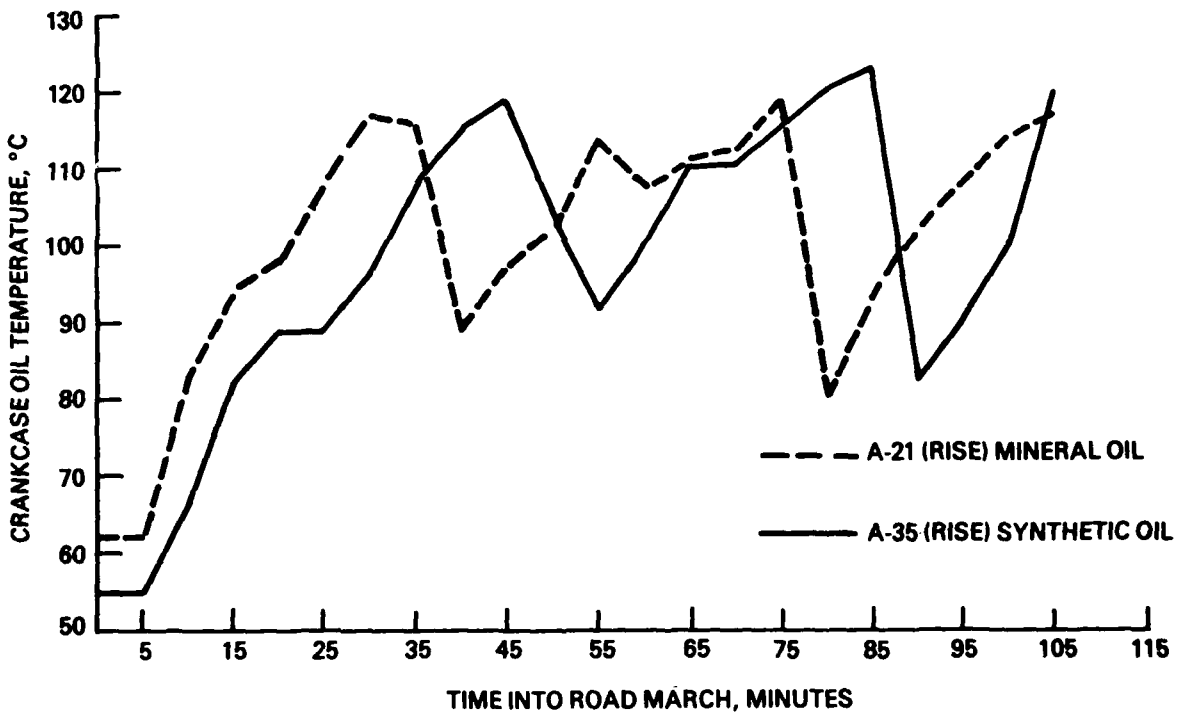

FIGURE 2. ENGINE OIL TEMPERATURE VS TEST TIME FOR RISE ENGINES

engines. This resulted in a high turnover rate for the tank engines. Table 6 shows a summary of vehicle miles (km), hours of operation, number of engine and transmission oil additions, and number of engine and transmission failures and replacements that occurred throughout the test program. There were no final drive failures or replacements for HQ-67 during the test.

As indicated in Table 6, there were fourteen engine and four transmission replacements during this test program. However, in their failure analysis, Fort Carson maintenance personnel have not charged the lubricant as being responsible for any of the failures. Table 7 provides a breakdown of engine and transmission replacements. Where possible, the cause of the replacement is shown. Although some of the engine failures could possibly be ascribed to oil-related problems, the maintenance personnel who disassembled the engines did not indicate that any of them were. After comparing, where possible, the performance of the MIL-L-2104C lubricants with that of the MIL-L-46167 arctic engine oil, it was determined that there were no statistically meaningful differences between the two. Each performed about as well as the other. It is unfortunate that only one M60A1 tank at Fort Carson was designated as a control vehicle since there were other tanks available. More useful data would have been generated and statistical manipulation of the data versus the test vehicle results would have been made possible. Even though the tank, HQ-66, generated some data, it was insufficient to allow computation of sample statistics. Thus, no statistical inferences could be made. However, it was possible to compare results derived at Fort Carson for the engines operated on MIL-L-46167 oil with those for the test and control groups at Fort Lewis. Because of the limited time factors imposed on organizational and support personnel to keep the tanks "combat ready," it was not feasible to hold an engine or transmission for disassembly and inspection by research personnel to determine the exact cause of failure for the affected components. Two separate comparisons were made during the test between the vehicles operated with the MIL-L-46167 engine oil and the other M60A1 tanks in the battalion operated with MIL-L-2104C oil as to failure rates of main engine generators and starters and lead-acid storage batteries (6TN). In the first comparison, data were extracted from material readiness reports for the period 1 November 1977 through 31 July 1978. A change in responsibilities for maintaning a prescribed load list (PLL) from battalion level to company

TABLE 6. FORT CARSON M60A1 VEHICLE OPERATIONAL DATA
(January 1977 - May 1979)

Vehicle No.	Total Hours	Total Miles (km)	Total Fuel, Gal (Liter)	Engine Make up (Quarts)	Trans Make up (Quarts)	Final Drive Make up (Quarts)	Oil MPG	Oil KPL	Fuel MPG	Fuel KPL	Number of Oil Change/Quarts Eng	Number of Oil Change/Quarts Trans	Number Component Replacements Engine	Number Component Replacements Transmission
HQ-67	154	1264 (2034)	1502 (5685)	117	94	10	10.8	18.4	0.8	0.3	1/66	0/	0	0
HQ-68	245	1639 (2638	2249 (8512)	51	0		32.1	54.6	0.7	0.3	0	0/	1	0
A-31	310	1249 (2010)	1617 (6120)	43	90		29.0	49.3	0.8	0.3	0	1/68	1	0
A-32	263	1436 (2311)	2168 (8206)	27	111		53.2	90.5	0.7	0.3	4/264	2.136	1	0
A-33	201	1505 (2422)	1822 (6896)	102	152		14.8	25.2	0.8	0.3	2/132	3/204	0	0
A-34	94	599 (964)	459 1737)	37	68		16.2	27.5	1.3	0.6	2/132	2/136	2	2
A-35	300	1866 (3003)	1670 (6321)	77	117		24.2	41.2	1.1	0.5	2/132	1/68	2	0
CONTROL VEHICLE														
B-11	534	2519 (4054)	3321 (12570)	96	28		26.2	44.6	0.8	0.3	1/66	0	1	0
HQ-66	19	168 (270.4)	230 (870.6)	0	44		---	---	0.7	0.3	0	0	0	0
OPERATIONAL DATA FROM JUNE 1979 - FEBRUARY 1981														
HQ-67	70	218 (351)	985 (3728)	80	20	0	2.7	4.6	0.2	0.1	2/132	4/272	1	0
HQ-68	120	352 (566)	1835 (6945)	89	77		4.0	6.8	0.3	0.1	3/198	2/136	1	1
A-31	266	294 (473)	2265 (8573)	66	83		4.5	7.7	0.1	0.05	6/396	3/204	2	0
A-32	291	906 (1458)	1928 (7297)	57	39		15.9	27.0	0.5	0.2	3/198	2/136	0	0
A-33	118	426 (686)	1529 (5787)	26	27		16.4	27.9	0.3	0.1	1/66	1/68	0	0
A-34	102	453 (729)	2083 (7884)	64	27		7.1	12.1	0.2	0.1	2/132	4/272	0	1
A-35	229	416 (669)	1918 (7260)	44	28		9.5	16.2	0.2	0.1	6/396	7/476	1	0
CONTROL VEHICLES														
B-11	92	744 (1197)	1055 (5993)	36	48		20.7	35.10	0.7	0.3	0	0	0	0
HQ-66	170	797 (1282)	1925 (7287)	38	82		21.0	35.6	0.4	0.2	1/66	1/68	1	0

TABLE 7. BREAKDOWN ANALYSIS OF FORT CARSON M60A1 ENGINE AND TRANSMISSION REPLACEMENTS

Vehicle No.	No. of Engine Replacements/Date	Reason for Removal
B-11 (Control)	1 (Sep 78)	High silicon content and metal wear. Aoap directed. New S/N 8218.
A-34 (Test)	1 (16 Dec 77 - 20 Mar 78)	Leaking injector pump shaft seal. New S/N 304.
A-31 (Test)	1 (21 Mar - 20 May 78)	Low compression of three cylinders. New S/N A0654.
A-35 (Test)	1 (21 Mar - 30 Jun 78)	Low compression of three cylinders. New S/N A0809.
HQ-68 (Test)	1 (21 May - 30 Jun 78)	Two rod bearings broke through crankcase. New S/N 6817.
A-34 (Test)	1 (1-30 Sep 78)	High silicon content and metal wear. AOAP directed. New S/N 6817.
A-32 (Test)	1 (1-30 Apr 79)	Leaking cooling fan seal. New S/N A0005.
A-35 (Test)	1 (1-30 May 79)	Rod broke through engine crankcase. New S/N 0283.
HQ-66 (Control)	1 (1-31 Jul 79)	Fan tower seal leaking.
HQ-67 (Test)	1 (1-30 Nov 80)	Rod broke through engine crankcase.
A-35 (Test)	1 (1-31 Dec 80)	Low compression in three cylinders. New S/N A02440.
A-31 (Test)	1 (1-31 Jan 81)	Reason unknown.
A-31 (Test)	1 (1-28 Feb 81)	Transmission drain plug fell out.
HQ-68 (Test)	1 (1-28 Feb 81)	Loss of Power.
	No. of Transmission Replacements/Date	
A-34 (Test)	1 (1-30 Sep 78)	Internal failure. New S/N 29227.
A-34 (Test)	1 (1-31 May 79)	Cracked case. New S/N 7630T.
A-34 (Test)	1 (1-31 Jan 81)	Loss of steering on right side. New S/N 42587.
HQ-68 (Test)	1 (1-28 Feb 81)	Loss of Power. New S/N 40813T.

level rendered much of the old data useless. However, enough data were retrieved so it appears that the vehicles operated with the MIL-L-46167 arctic oil used fewer lead-acid batteries, starters and generators. The second comparison compared the usage rate for the components stated above between the vehicles operated on MIL-L-46167 and two platoons of tanks using MIL-L-2104C for the period 15 December 1979 through 29 February 1980. The results of this comparison were the same as the results of the first comparison and tended to reinforce the conclusion reached in that case.

b. M151A2 Jeeps

These vehicles were operated in accordance with normal mission/training requirements. This test was straightforward and contained no unexpected results. The vehicles operated satisfactorily throughout the test period with little maintenance. Table 8 provides a summary of the operational data for the three test vehicles and the one control vehicle. The remarks made above about having only one vehicle designated as a control vehicle apply here.

B. Results of Test

1. M60A1 Tanks

During the first phase of the pilot fleet test, January 1977 through 20 April 1977, both the MIL-L-46167 arctic engine oil and the MIL-L-2104C OE/HDO 30 or 50 grade oils performed in a similar manner and appeared to operate as an engine lubricant equally well except there were subjective comments made by user personnel to the effect that those engines operated with the MIL-L-46167 oil started easier and seemed to have more power (8). There was some comment in the beginning about engines overheating; however, after the engine oil temperatures were compared (Figures 1 and 2) in the field test performed for that purpose, the factor of overheating did not come up again during any other phase of testing. The period September 1977 through May 1979 resulted in the M60's being operated in different environments such as fire and maneuver exercises, which resulted in the largest accumulation of miles and hours of operation and searchlight detail which resulted in low mileage but a large number of hours of operation. Throughout this period, both lubricants appeared to perform equally well except that, again, subjective comments indicated that the engines operated with

TABLE 8. SUMMARY OF M151A2 VEHICLE OPERATIONAL DATA

Veh. No.	Total Miles (km)	Total Fuel Gal. (liters)	MPG (KPL)	Number Oil Changes	Make up Oil Quarts	MPQ (KPL)	Serial No.	Maintenance Performed
				TEST VEHICLES				
HQ-9	21404 (34446)	1750 (6624)	12.2 (5.2)	7	9	2378 (4044)	5029116	Seven oil changes directed by the AOAP laboratory.
P-7/ 41	5874 (9453)	672 (2544)	8.7 (3.7)	2	3	1958 (3330)	5029165	1) Rocker arm cover gasket replaced. 2) Oil change due to unit personnel erroneously adding 1 qt. OE/HDO30. 3) Transmission repaired. 4) Clutch repaired. 5) Oil change directed by AOAP lab. 6) Clutch repaired.
P-17	6241 (10044)	582 (2203)	10.7 4.5)	3	5	1248 (2122)	5028906	1) R/R engine assembly, pump assembly, engine oil, gasket set, oil pan gasket. 5 qts. test oil added. 2) Read crank shaft seal, rocker arm cover gasket, oil pan gasket replaced. 3) Head gasket replaced. 4) Oil change directed by AOAP lab.
				CONTROL VEHICLE				
P-73	7416 (11935)	716 (2710)	10.4 (4.4)	2	3	2472 (4204)	5029136	1) Flywheel parts kit installed; rocker arm gasket, oil pan gasket, rear main seal replaced, engine tuned. 2) Clutch repaired. 3) oil change directed by AOAP lab.

the MIL-L-46167 arctic engine oil tended to start easier in all weather conditions and appeared to use fewer main engine generators and starters and 6TN lead-storage batteries. In the monthly informational reports submitted by maintenance personnel, it was mentioned several times that the vehicles operated with the MIL-L-2104C lubricants used more generators, starters, and 6TN batteries than the vehicles operated with MIL-L-46167. The third phase of the pilot fleet test, June 1979 through February 1981, was relatively inactive for the test units involved with a greatly reduced number of operating miles and hours. The records indicated that engine and transmission replacements continued to occur at the same rate. B-11, operated with MIL-L-2104C oil, had charging problems throughout the month of November 1980. It burned up two generators and required several voltage regulators and six new batteries.

b. M151A2 Jeeps

There were three comments prevalent throughout the test period for the M151A2 vehicles. These were that the vehicles operated with MIL-L-46167 arctic engine oil required fewer tune-ups, started easier in all weather conditions, and were more likely to develop leaking gaskets and seals than those vehicles operated with the MIL-L-2104C lubricants. There did not appear to be, nor were any specific comments made about, any change in component failures for engines operated on the control or test oils. There were no statistical differences between the results achieved by either the MIL-L-46167 or the MIL-L-2104C oils.

III. FORT LEWIS TESTING

A. Details of Test

1. Test Materials

The lubricants used in this portion of the pilot fleet test were the same as those used at Fort Carson, a second MIL-L-46167 arctic engine oil and the standard issue MIL-L-2104C OE/HDO 30 grade or 50 grade, depending on changes directed by the pertinent lubrication orders due to seasonal temperature ranges.

2. Test Fleet

In March 1979, six M60A1 tanks at Fort Lewis, WA were placed in the pilot fleet test. The test plan utilized for the Fort Carson pilot fleet test was also utilized for the Fort Lewis vehicles. The vehicles were divided into two groups of three vehicles each; the three test vehicles used MIL-L-46167 arctic engine synthetic oil, and the three control vehicles used MIL-L-2104C OE/HDO 30 grade or OE/HDO 50 grade, depending on seasonal temperatures and applicable lube orders. The three test vehicles were totally converted to the MIL-L-46167, i.e., engines, transmission, and final drives.

3. Fleet Operations

The test and designated control vehicles were operated in accordance with normal mission/training requirements. The activities and use for the test period March 1979 through July 1981 corresponded to the activities and use at Fort Carson for the test periods January 1977 through April 1977 and September 1977 through May 1979.

Table 9 presents operational data reported on those vehicles involved in the evaluation. The disparity in oil changes between the test and control vehicles is due to contamination of the test lubricant during a major field exercise at Yakima Firing Range. The tank crews, by mistake, used aircraft turbine oil as make up lubricant, thereby necessitating oil changes in most of the components on the test vehicles.

TABLE 9. FORT LEWIS M60A1 VEHICLE OPERATIONAL DATA
(March 1979 - August 1983)

Vehicle No.	Total Hours	Total Miles (km)	Total Fuel, Gal (Liter)	Engine Make up (Quarts)	Trans Make up (Quarts)	Final Drive Make up (Quarts)	Oil MPG	Oil KPL	Fuel MPG	Fuel KPL	Number of Oil Change/Quarts Eng	Number of Oil Change/Quarts Trans	Number Component Replacements Engine	Number Component Replacements Transmission
						TEST								
B-13	142	830 (1336)	1834 (6942)	8	16		103.7	(176.4)	0.5	(0.2)	5/330	3/204	0	3
B-22	287	1477 (2377)	3225 (12207)	14	12		105.5	(179.4)	3/198	(0.2)		3/204	1	1
B-34	205	1028 (1654)	2367 (8959)	13	8		79.0	(134.3)	0.4	(0.2)	5/330	6/408	1	1
						CONTROL								
A-12	345	1799 (2895)	2181 (8255)	18	16		99.9	(169.9)	0.8	(0.3)	5/330	4/340	1	2
A-15	241	1128 (1815)	1490 (5640)	12	20		94.0	(159.9)	0.8	(0.3)	4/264	3/204	0	0
A-33	332	1907 (3069)	2883 (10912)	16	24		119.1	(202.5)	0.7	(0.3)	2/134	1/68	0	0

Table 10 provides a breakdown analysis of engine and transmission replacements and shows that all of the test vehicles, B-13, B-22, and B-34, and one control vehicle, A-12, experienced maintenance problems leading to component replacement during the evaluation period. However, the causes of replacements of these components were not considered related to the use of the MIL-L-46167 lubricant. In the case of the transmission replacement on vehicle B-34, in September 1980, the unit did not follow established reporting procedures; consequently, the failed transmission was not inspected by the quality assurance branch of the maintenance division.

B. Results of Tests

There were four engine replacements, seven transmission replacements, and two final drives changed during the test period at Fort Lewis. There were no subjective comments received from user personnel or maintenance personnel about any improvement in operation of the M60 tanks. Based solely on the statistical analysis of the two small samples (three M60A1 tanks in each group), there were no differences in the operation of the test vehicles when compared to the control vehicles. By default, then, it could be inferred that one oil performed as well as the other.

IV. CONCLUSIONS

The MIL-L-46167 arctic engine oil apparently performed as well as the MIL-L-2104C OE/HDO 30 grade or OE/HDO 50 grade oils during the test period with the added commendations of user and maintenance personnel at Fort Carson, CO that those engines lubricated with the OEA started easier in all weather conditions and used less main engine generators and starters and lead-acid (6TN) batteries.

No oil-related failures could be positively identified as the causes for replacements of engines, transmissions, and final drives. No final drive failures of any kind were reported at Fort Carson during the almost 3-year period that they were included in the test (Hq. 67 only), and only two final drives were replaced during the 29 months that Fort Lewis was included in the test. M151A2 jeeps lubricated with the MIL-L-46167 lubricant required fewer tune-ups and started easier in all weather conditions than those operated with the MIL-L-

TABLE 10. BREAKDOWN ANALYSIS OF M60A1 ENGINE AND TRANSMISSION REPLACEMENTS

Fort Lewis, Washington

Vehicle No.	Date	Component	Reason for Replacement
A-12 (Control)	Jun 80	Engine	Fuel dilution in left cylinder bank.
B-34 (Test)	Sep 80	Engine	High silicon content.
B-22 (Test)	May 81	Engine	High silicon content.
B-34 Test)	Jul 81	Engine	High metal wear.
B-13 (Test	May 79	Transmission	Loose torque converter nut.
B-13 (Test)	Oct 79	Transmission	Bands improperly adjusted.
A-12 (Control)	Jun 80	Transmission	Excessive leading and overheating.
B-34 (Test)	Sep 80	Transmission	Reason unknown.
A-12 (Control)	Apr 81	Transmission	Rear band inoperative.
B-13 (Test)	Jul 81	Transmission	Low range inoperative.
B-22 (Test)	Jul 81	Transmission	Slippage in low and reverse ranges.

2104C oils. However, leaking gaskets and seals were more prevalent in the test vehicles than the control vehicles.

- The MIL-L-46167 arctic engine oil may be used to lubricate the engines, transmissions, and final drives in M60A1 tanks.
- The MIL-L-46167 OEA may be used to lubricate the modified engines in the M151A2 jeeps.
- Caution should be used to ensure that engine overheating does not become a problem in the M60A1 tanks, especially those equipped with non-RISE engines.
- Caution should be observed to prevent oil loss in the modified M151A2 jeep engines due to leaking gaskets and seals.
- Insufficient information concerning the exact number of accessory engine components (main engine generators, starters, and lead-storage batteries) replaced on test and control engines was documented to allow any meaningful conclusions.
- An insufficient number of control vehicles were designated at Fort Carson to allow a statistical comparison of data generated by the test vehicle group and the control vehicle group.

V. RECOMMENDATIONS

Based on information generated in this evaluation, the following actions are recommended:

- Expand program to include all operational vehicles in an entire battalion.
- Designate a sufficient number of control vehicles in future field tests so that statistical comparisons may be made between data generated by test and control groups.
- Include in the operating instructions for future field tests the requirement that designated accessory engine components be tracked through the prescribed load list (PLL) for real usage data so that comparisons may be made between test vehicle groups and control vehicle groups.

REFERENCES

1. U.S. Military Specification, MIL-M-63004B(TM), "Manuals, Technical: Preparation of Lubrication Orders," Amendment 2, May 1980.

2. DRCPM-M-60 TD letter dated 3 April 1976 to 4th Inf. Div. (Mech) at Fort Carson, Colorado.

3. USAMSAA Final Report of R and D Field Liaison Visit to Fort Carson and 4th Infantry Division (Mech), (Trip No. 75L04) dated 19-23 May 1975.

4. U.S. Military Specification, MIL-L-2104C, Lubricating Oil, Internal Combustion Engine, Tactical Service, November 1970.

5. U.S. Military Specification, MIL-L-46167, Lubricating Oil, Internal Combustion Engine, Arctic, Amendment 1, May 1978.

6. Interim Report AFLRL No. 118 "Use of Multiviscosity/Synthetic Engine Oil in Army Combat/Tactical Vehicles," ADA081444, dated September 1979.

7. "Engine Oil Operating Temperatures--Mineral vs Synthetic," DF Report from Maintenance Tech, 1/77 Armor (WAN6AA), to Commander, 4th Inf. Div. (M), 19 October 1979.

8. Fort Carson Final Report on Synthetic Arctic Engine Oil, 12 April 1977.

9. "Used Oil Analyses-Fort Carson Pilot Fleet Test W/APG PD-1," Letter Report, AFLRL to DRDME-GL, 15 May 1978.

APPENDIX A

PILOT FLEET TEST PLAN

PILOT FIELD TEST PLAN

FOR FT. CARSON, CO

JANUARY - APRIL 1977

Purpose

To determine feasibility of using synthetic arctic engine oils in outside arctic operated combat/tactical vehicles.

Scope

Three M60 vehicles, powered by TCM AVDS 1790-2A engines, will be subjected to normal mission/training operations. Two vehicles will use APG PD-1 synthetic arctic engine oil provided by USAMERADCOM/AFLRL and one vehicle will provide a baseline (or reference case) operating using MIL-L-2104C OE/HDO-30 provided from Ft. Carson Supply.

Procedure

I. Pretest Vehicle and Engine Inspection/Preparation

A. Inspection

Review engines' operational/maintenance history for three selected vehicles. If a potential problem area is noted for a given engine, the engine will be replaced with another provided by DIO; see engine list attached.

B. Preparation

Before draining the original MIL-L-2104C, record oil pressure under fully warmed-up operating conditions for each engine. Drain the MIL-L-2104C single grade engine oil from the three test vehicle engines while the oil is warm. Retain a 12-oz. sample from each engine. Change engine oil filters and charge two engines with APG PD-1 test oil and one engine with MIL-L-2104C OE/HDO-30. A flush of the previous oil is not required. Warm-up the engines and obtain a 9-oz. sample from each engine using a suitable syringe and tubing to extract

the oil through the dip-stick tube. Repeat the oil pressure measurement for all three engines in the same manner as described above. The oil samples must be identified with same information described in Section IIC.

II. Lubricant Testing

A. Duration

Subject the test vehicles to normal mission/training operation during period January through April 1977. No engine oil changes are to be made except as covered in Section III.

B. Information To Be Recorded

The following information should be maintained during course of the test in the form of a "Test Diary":

1. Oil Consumption: Date, hours, miles and quantity added.
2. Fuel Consumption: Date, hours, miles and quantity added.
3. Engine Maintenance: Date, action, reason; i.e., scheduled or unscheduled.
4. Changes in engine power/performance (i.e., good, better or worse).
5. Indications, if any, of oil leakage, and continuous observations of such leakage as long as it continues.

NOTE: For items 4 and 5, observations of both the operating crew and maintenance personnel should be made and recorded in the Test Diary. Comments relating to any of the above items or any unusual operations which may be of significance should also be recorded in the Test Diary.

C. Oil Sampling and Identification

After the initial oil sample is taken at start of test, a 9-oz. sample of warm oil should be taken from the engine every month or 25 hours of engine operation. Each sample must be identified as follows:

1. Vehicle USA No.

2. Engine S/N

3. Vehicle miles (total on vehicle).

4. Engine hours (total on vehicle).

5. Date of Sample.

Samples should be mailed to:

U.S. Army Fuels and Lubricants Research Laboratory
% Southwest Research Institute, Attn: S.J. Lestz
P. O. Box 28510
San Antonio, Texas 78284

D. Conclusion of Test

On completion of test, a final oil sample of two gallons should be taken from each engine when the oil is drained. This sample should also be identified in the same manner as the other samples. All oil filters from each engine should be removed, packaged, and marked in same manner as the final oil drain sample.

III. Supplementary Information

A. Lower Oil Pressure

It is expected that due to its lower viscosity, the arctic engine lubricant will cause the engine-oil low pressure light/alarm to be activated during idle speeds. Operating personnel should be advised of this condition and that the engines will operate at lower oil pressure over the entire speed range.

B. Oil Changes

Since it is the intention of this field test to determine if the engine oil can reduce routine maintenance and improve vehicle readiness, there will be no oil changes during the test. Exceptions to the above are as follows:

1. If the DIO and Commander decide that the one vehicle using the OE/HDO-30 should be changed to the next higher viscosity grade due to expected

temperature warming, then in accordance with the LO, the OE/HDO-30 will be changed. However, it would be highly desirable to use only OE/HDO-30 through the winter, and change the oil only if its condition indicates a change is needed.

2. If laboratory analyses of the OE/HDO-30 or the arctic engine oil indicate an oil change is merited, then notification for a change will be issued.

C. Engine Maintenance

Maintenance Division, DIO will provide maintenance support above organization level.

1/77 ARMORED BATTALION ENGINE HISTORY

HQ-66

Use MIL-L-2104C, OE/HDO-30

Mfg. in 1975
Original Engine
181 Hours
1433 Miles

HQ-67

Use APG PD-1

Mfg. in 1975
3rd Engine SN 1074
68 Hours
541 Miles

HQ-68

Use APG PD-1

Mfg. in 1975
4th Engine SN 8962
69 Hours
383 Miles

(Repaired - Maint. Div. - 11 March 1976
1 Cylinder & Piston Replaced
Other Cylinder > 300 psi
Dyno Run - 675 hp + 108 = 783 hp
issued.)

APPENDIX B

M-151A2 TEST PLAN

M-151A2 FIELD TEST PLAN

FOR FT. CARSON, CO

Purpose

To assess the feasibility of using multiviscosity synthetic arctic oil in conjunction with low-blowby piston rings developed for the M-151 vehicle, to allow extended drain intervals or no-oil-drain operation of the M-151 vehicle.

Scope

Four M-151 vehicles, equipped with modified pistons and low-blowby piston rings will be subjected to normal post operation. Two vehicles will use the APG PD-1 synthetic arctic engine oil as specified by USAMERADCOM and one vehicle will use MIL-L-2104C OE/HDO-30 from Ft. Carson supply, to provide a baseline or reference case.

Procedure

I. Pretest Vehicle and Engine Inspection/Preparation

A. Installation

The four engines fitted with special low-blowby piston rings and provided by the Army Fuels and Lubricants Research Laboratory (AFLRL) should be installed in the M-151 vehicles, with the standard engines removed and stored for later replacement. It is suggested that these engines be stored in the engine-shipping crates, which will be required at test completion.

B. Preparation

The cooling systems should be filled according to normal operating procedures for the climatic conditions. The three test engines should be charged with the APG PD-1 test oil. The vehicle to be used as a reference should be drained of oil while warm. An 8-oz. sample of this drain should be taken. Change the engine oil filter and charge the engine with MIL-L-2104C OE/HDO-30.

Warm up the engines and obtain a 3-oz. sample from each engine using a suitable syringe and tubing to extract the oil through the dip-stick tube. The oil samples must be identified with the same information described in Section IIC.

II. Lubricant Testing

A. Duration

Subject the test vehicles to normal mission/training operation. No engine oil changes are to be made except as covered in Section III.

B. Information To Be Recorded

The following information should be maintained during course of the test in the form of a "Test Diary":

1. Oil Consumption: Date, hours, miles and quantity added
2. Fuel Consumption: Date, hours, miles and quantity added
3. Engine Maintenance: Date, action, reason; i.e., scheduled or unscheduled.
4. Changes in engine power/performance (i.e., good, better or worse).
5. Indications, if any of oil leakage, and continuous observations of such leakage as long as it continues.

NOTE: For items 4 and 5, observations of both the operating crew and maintenance personnel should be made and recorded in the Test Diary. Comments relating to any of the above items or any unusual operation which may be of significance should be recorded in the Test Diary.

C. Oil Sampling and Identification

After the initial oil sample is taken at start of test, a 3-oz. sample of warm oil should be taken from the engine every month or 3000 miles of operation. Each sample must be identified as follows:

1. Vehicle USA No.
2. Engine S/N.

3. Vehicle miles (total on vehicle).

4. Date of Sample.

Samples should be mailed to:

U.S. Army Fuels and Lubricants Research Laboratory
% Southwest Research Institute
Attn: J.D. Tosh
6220 Culebra
San Antonio, Texas 78284

D. Conclusion of Test

On completion of test, a final oil sample of approximately one gallon should be taken from each engine when the oil is drained. This sample should also be identified in the same manner as the other samples. All oil filters from each engine should be removed, packaged, and marked in same manner as the final oil drain sample. The four test engines should be drained of all fluids and removed from the vehicles. The engines should then be crated and shipped to AFLRL for post-test disassembly and inspection.

III. Supplementary Information

A. Lower Oil Pressure

It is expected that due to its lower viscosity, the arctic engine lubricant may cause the engine-oil low pressure light/alarm to be activated during idle speeds. Operating personnel should be advised of this condition and that the engines will operate at lower oil pressure over the entire speed range.

B. Oil Changes

Since it is the intention of this field test to determine if the engine oil can help reduce routine maintenance and improve vehicle readiness, there will be no oil changes during the test. Exceptions to the above are as follows:

1. If the DIO and Commander decide that the one vehicle using the OE/HDO-30 should be changed to the next higher viscosity grade due to expected temperature warming, then in accordance with the LO, the OE/HDO-30 will

be changed. However, it would be highly desirable to use only OE/HDO-30 through the winter, and change the oil only if its condition indicates a change is needed.

2. If laboratory analyses of the OE/HDO-30 or the arctic engine oil indicate an oil change is merited, then notification for a change will be issued.

C. Engine Maintenance

Maintenance Division, DIO will provide maintenance support above organization level.

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